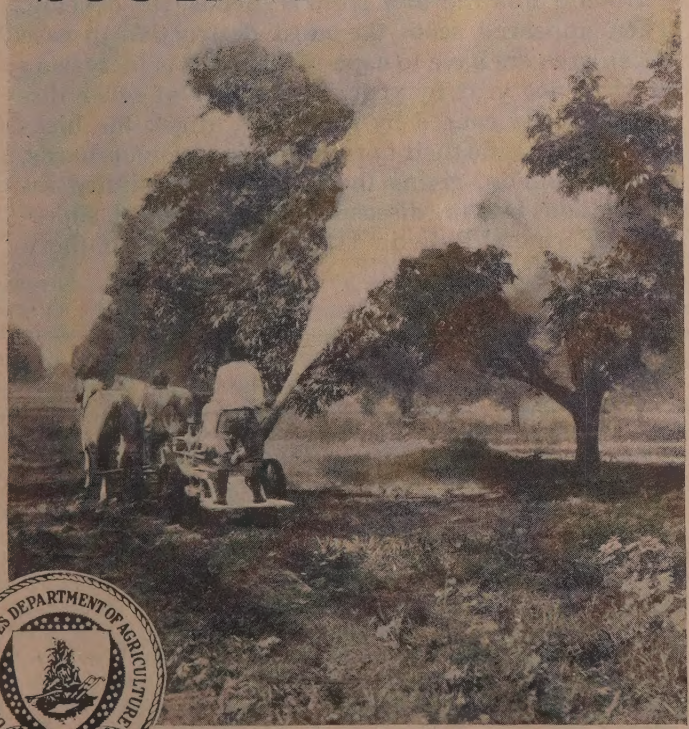
IMPERIAL MYCOLOGICAL
IMPERIAL BUREAU
AGRICULTURAL PARASITOLOGY
2 MAR. 1935
Demarée J.B. 1931

U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1672

DISEASES OF PECANS IN THE SOUTHERN STATES



IMPERIAL MYCOLOGICAL
2 MAR. 1935
INSTITUTE

DISEASES OF PECANS are becoming of more economic importance every year. When the industry was in its infancy, early in the present century, they were of minor economic concern to the grower, and little was known about them.

Rosette was the first serious menace to develop. Then appeared scab, the most destructive disease pecan growers have to cope with, and it is increasing in virulence year by year. A number of other diseases, chiefly caused by fungi that attack the hickories, have made their appearance in pecan orchards.

This bulletin, giving the results of continued investigations into the diseases and their control, supersedes Farmers' Bulletin 1129, Diseases of Southern Pecans.

Washington, D. C. Issued October, 1931

DISEASES OF PECANS IN THE SOUTHERN STATES

By J. B. DEMAREE, *Pathologist, Division of Horticultural Crops and Diseases, Bureau of Plant Industry*

CONTENTS

	Page
Introduction	1
Diseases due to specific organisms	2
Scab	2
Leaf blotch	7
Brown leaf spot	8
Nursery blight	9
Crown gall	11
Powdery mildew	12
Western sooty spot	12
Gnomonia leaf spot	13
Downy spot	13
Wood rots	13
Diseases due to environmental factors	14
Rosette	14
Sand burn	17
Little leaf	18
Winter injury	21
Edema	22
Spraying	22
Preparation of Bordeaux mixture	23
The spray outfit	24
Applying the spray	25

INTRODUCTION

PECAN GROWING as an industry has developed since 1900 and is of recent origin as compared with the commercial growing of apples and peaches. Until rather recent times little was known about pecan diseases. Prior to 1910 they were of little economic importance. Rosette was the first to develop in a menacing manner and give the growers considerable concern. Later scab made its appearance in commercial plantings, attacking at first only one or two varieties of much importance. Scab is now by far the most destructive disease growers have to contend with and is increasing in importance from year to year.

Other diseases, such as leaf blotch, brown leaf spot, and nursery leaf blight, cause serious damage in some localities in the southern pecan belt, while diseases known as little leaf, edema, and crown gall are of less importance.

It is the purpose of this bulletin to give in a concise, clear, and nontechnical manner such information on pecan diseases as is at present available. Illustrations are presented wherever these will be an aid to readers in recognizing the diseases discussed and to help them distinguish between diseases of major importance and those considered as of only minor importance.

In Farmers' Bulletin 1129, Diseases of Southern Pecans, which is superseded by this bulletin, it was predicted that if due regard were given to the choice of suitable orchard sites, the selection of varieties with special reference to resistance to disease, and proper care of the orchard after it is planted diseases need be of only minor importance and might be expected to decrease. That prediction has

been fulfilled only in part. Growers have used greater discrimination in the selection of varieties and orchard sites, and there has been improvement in the care of orchards during the past 10 years. Even so, to-day, with the possible exception of rosette, the earlier-known pecan diseases attack the trees with more virulence than formerly. In the case of scab more varieties are susceptible, and virulent strains of the scab fungus are more widely disseminated. The brown leaf-spot disease has developed from one of minor to one of major importance. Leaf blotch, downy spot, western sooty spot, and Gnomonia leaf spot, now present in many orchards, either were not known 10 years ago or were considered of little importance.

Most fungous diseases that attack pecans also attack hickories, and in most cases the organisms causing pecan diseases were first reported on hickories. It is not known whether these organisms originally were hickory or pecan parasites. Nevertheless, the pecan now seems to be the favorite host of the various fungous parasites capable of attacking the hickory group of trees, of which the pecan is the most important nut producer.

DISEASES DUE TO SPECIFIC ORGANISMS

SCAB

The fungus[1] causing pecan scab is becoming more abundant each year in the humid sections of the southeastern pecan-growing region and is gradually extending into the newer pecan regions where conditions are favorable for its growth. Since the disease is one of the principal limiting factors in pecan-nut production, its control is of prime importance to the new and growing pecan industry in the southeastern part of the United States. The disease may attack the nuts, twigs, and leaves. Some of the best commercial varieties are highly susceptible to it. (Fig. 1.) Although some injury is done to all parts of the trees attacked, the greatest damage is to the nuts. In many localities it annually causes a heavy loss of the crop of the varieties Schley, Delmas, Alley, Pabst, Van Deman, and Success in untreated orchards. There is evidence to show that the fungus causing the disease is gradually adapting itself to Moneymaker, Stuart, and Frotscher, varieties at one time considered highly resistant or possibly immune. Recent experiments indicate that there are different strains or races of the fungus, a fact which explains why scab does not always attack the same varieties alike in all localities.

DESCRIPTION AND LIFE HISTORY

The results of early spring infections frequently are observed first as elongated brown or black lesions along the veins on the under sides of the leaves. Also the early infections frequently cause elongated spots on the ridges of the young nuts. Spots that appear later in the season on leaves, twigs, and nuts as a rule are brown or black, circular (one-eighth to one-quarter of an inch in diameter), and slightly raised above the surrounding tissues. (Fig. 1.) If

[1] *Cladosporium effusum* (Wint.) Demaree.

abundant, the spots on the nuts may coalesce and form large irregular black blotches. In extreme cases, infections on the nuts may be so numerous as to blacken the entire surface. Severely attacked nuts may blacken and drop prematurely, or they may die and remain attached to the twigs for several months.

The disease is carried over from one season to another in the spots on twigs, nuts, or leaf stems. Under favorable weather con-

FIGURE 1.—Pecan scab on leaves, a twig, and a nut

ditions in April and May, the dormant fungus within the last year's scab spots becomes active and produces spores that infect the new leaves.

Frequent April rains and a low percentage of sunshine favor early spring infections. Under such conditions, initial infection may occur prior to the middle of April in the latitude of southern Georgia; and by the latter part of April or the first week in May, there may be many secondary infections. The young leaves are extremely susceptible while they are unfolding and developing, but become

more resistant as they grow older. As soon as the leaves are fully grown and have taken on a dark-green color they are practically immune. The nuts are susceptible until almost fully grown, but only the tender succulent portions of the current season's twig growth are subject to attack. The number of early spring infections can be reduced perceptibly by practicing sanitary measures.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Pecan scab is widely distributed throughout the Southeastern States, having been reported from North Carolina, South Carolina, Georgia, Florida, and Alabama, also from Mississippi, Louisiana, Arkansas, and Texas. The disease causes most damage in the territory embracing northern Florida and the southern portions of Georgia, Alabama, Mississippi, and Louisiana. In this region the disease not only attains its greatest degree of destructiveness but a greater number of varieties are attacked than elsewhere. In the northern half of Georgia, Alabama, Mississippi, Louisiana, and eastern Texas the disease has not yet become serious except on one or two very susceptible varieties, and it is almost absent in the drier regions of Texas. Fewer pecan orchards, lower percentages of humidity, and less frequent summer rains in the more northern and western pecan districts are undoubtedly the main factors contributing to the lesser prevalence of the disease there.

Most varieties are susceptible to infection, but whether or not a variety succumbs to the disease in a section where the fungus thrives depends upon the introduction of a strain or race of the fungus capable of attacking that particular variety. Susceptible varieties may appear immune for a limited period in isolated orchards or even over extensive areas and later succumb to the disease when a suitable strain of the causal organism is introduced and becomes established. The various strains are becoming more uniformly distributed in regions where weather conditions favor the development and propagation of the fungus.

METHODS OF CONTROL

SPRAYING

Extensive experiments over a series of years have demonstrated the efficacy of certain fungicides for controlling pecan scab. Homemade Bordeaux mixture has proved to be the most effective and dependable fungicide so far tried, and has been generally adopted as the standard spray in spite of the fact that under certain unfavorable weather conditions serious foliage injury may result. This type of injury is favored by droughts during August and September. The danger of such injury is greatly lessened if the strength of the Bordeaux mixture is reduced to that of the 3–4–50 formula—3 pounds of copper sulphate, 4 pounds of hydrated lime, and 50 gallons of water. Bordeaux mixture of this composition will hereafter be referred to as 3–4–50 Bordeaux mixture, with the understanding that it is the equivalent of what is commonly called the 3–3–50 mixture, in which the lime is quicklime or stone lime.

The number of applications required for commercial control of scab varies according to the variety, weather conditions, and the distri-

bution of infection sources in the orchard. If the twigs are not badly infected, or if spraying has been carefully done for two or more years, three applications at intervals of about one month should give commercial control. If the trees are badly infected and no previous treatments have been made, heavy early leaf infections are likely to result and four to five applications should be made. Even in spite of thorough spraying in a badly infected orchard the first year's treatment frequently results in unsatisfactory control. Benefits from spraying for the control of pecan scab are cumulative, and the ease and certainty of good control increase with each season's work. A cessation of treatment, as an economy measure during seasons of light crops, loses to the grower all cumulative advantages of previous years' treatments by permitting the reestablishment of the fungus in the orchard. The grower gambles the cost of a year's treatment against the value of a future crop when he permits a respite in the control work for even one year. It is advisable, therefore, to spray annually even though the crop some years may be so light that its value will barely compensate for the money expended on fungicides and labor.

The first application of spray should be made as soon as it is reasonably certain that the pistillate blossoms have been pollinated. Preblossom applications may severely injure the unfolding leaves, which are very susceptible to spray injury. Because it is not good practice to spray while the pistillate blossoms are exposed prior to pollination, the first application should be delayed until after the pollination period. Pollination is considered complete when the tips of the small nutlets have turned brown or black.

Spraying is not a cure for pecan scab; it serves only as a protection against infection. Applications, therefore, should be made frequently enough to keep the nuts covered with a fine film of the fungicide during their entire growing season. Applications at intervals of three to four weeks should accomplish this purpose. (For further information and directions with regard to spraying, see the section on that subject, beginning on page 22.)

DUSTING

Several types of dust fungicides have been tested to determine their efficacy in controlling pecan scab. The following have been used: Flowers of sulphur, colloidal sulphur, oxidized sulphur, dehydrated Bordeaux mixture, and monohydrated copper sulphate and lime dust.

None of the materials tested have given satisfactory results except the monohydrated copper sulphate and lime dust. Under the test conditions, however, this fungicide has not given as good results as Bordeaux mixture. To get the same results as with Bordeaux mixture, more applications at shorter intervals must be made. Four to six applications furnish about the same protection as three to four applications of Bordeaux mixture. The copper-lime dust most commonly used is composed of 20 per cent monohydrated copper sulphate and 80 per cent hydrated lime. This mixture analyzes about 7 per cent copper.

The writer has obtained the best results by making the applications in the early morning while the leaves and nuts are coated with

a film of dew or rain. To effect a more even distribution of the fungicide, the dust should be applied from two sides of the trees. When dusting very large trees it is advisable to drive the machine zigzag from one side of the tree row to the other, returning on the same row zigzagging in the opposite direction. This plan will enable the operator to distribute the dust evenly to all sides of the trees.

The amount of dust to be used is determined by the size of the trees. Trees averaging 50 to 60 feet in height and 40 to 50 feet in spread of branches require 10 to 12 pounds per application. Smaller trees require a proportionately smaller amount.

FIGURE 2.—Young diseased leaves. The previous year's infected shucks often remain attached to the twigs over winter and become a source of infection of the young leaves the following spring

ORCHARD SANITATION

Orchard sanitation in pecan-scab control has for its object the disposal of all hold-over sources of infection, as completely as possible, in order to prevent early leaf infection the following season. The fungus lives through the winter on infected twigs, shucks, and leaf stems. Frequently the infected shucks of the previous year cling to the twigs all winter and become important sources of the early spring leaf infections. (Fig. 2.) All such shucks should be removed from the trees before the opening of the growing season, as they are potential sources of infection. An effective method of disposing of them is to plow them under with a turnplow, which places the infected parts so deeply beneath the surface that they are not dragged out by later cultivation. Some growers who own or control extensive acreages of pecans claim that it is not practical to use the turnplow; they use instead disk harrows.

If the sanitation methods are to be complete and effective, the early plowing or disking, if done, should be completed before the opening of the leaf buds; and, to lessen the dispersion of spores from the infective material during the period that the young leaves are so susceptible, further cultivation should lapse until after the first application of spray or dust is made. When the sheet method of harvesting is employed the infected shucks can easily be gathered and removed from the orchard at a small cost. This method of

harvesting is not only advisable from the standpoint of disease control, but is also recommended as a means of destroying the larvae of the pecan-shuck worm.

There is no known method of destroying the sources of infection on the twigs. Summer spraying with Bordeaux mixture, however, will largely prevent twig infection. The twigs, therefore, should be relatively free from scab lesions after the first season of spraying.

In southern Georgia, pecan leaves normally begin to unfold during the last week of March, and as the terminals elongate, continue to unfold over a period of about six weeks. The pistillate blossoms become exposed to view some years as early as the middle of April. There is a period of four or five weeks, therefore, during which it is not considered safe to spray, even though the young leaves are then extremely susceptible to infection, because of the danger of injury to the blossoms and the young leaves. The importance of practicing sanitation measures to prevent the leaves from becoming infected during this period can not be overemphasized. Each new infection produces hundreds of spores capable of infecting the later formed leaves and young nuts.

LEAF BLOTCH

The first sign of the leaf-blotch disease[2] is the appearance of brown to greenish-brown spots on the under surfaces of the leaf blades, which later become almost black, due to the presence of minute black pimplelike bodies. The latter stage is the most conspicuous form of the disease and gives it the common name, leaf blotch. The spots, or blotches, vary from one-eighth to one-half inch in diameter, and frequently spots unite to form large irregular blotches which may involve the entire lower leaf surface. (Fig. 3.)

Leaf blotch is a disease of pecan foliage first observed in 1921. Gradually extending its range of distribution, it is now found in practically every pecan nursery and orchard in northern Florida and the southern part of Georgia, Alabama, Mississippi, and Louisiana.

The disease is first found in late June or early July on the older leaflets and may gradually increase until all mature leaves are spotted or killed. On nursery trees the disease first appears on the lower and older leaves, but as the season advances the other leaves are also attacked. Defoliation progresses upward till the first of November, when only a few of the youngest leaves remain. Of the several foliage diseases of budded or grafted nursery trees, blotch is often the most prevalent and is usually responsible for premature dropping of the leaves.

Injuries caused by rosette, general neglect, or any other factor or factors tending to lower the vitality of the trees predispose them to attack by the leaf-blotch fungus. Trees too thickly planted or growing on land receiving no cultivation or fertilizer often lose from one-half to three-fourths of their leaves prior to the harvest season on account of leaf blotch. As a result of such premature defoliation the nuts are of inferior quality, and the crop is light the following season. Trees growing in good soil, well fertilized and properly cultivated, are not attacked so severely as neglected trees.

For suggested methods of control see Brown leaf spot.

[2] Caused by *Mycosphaerella dendroides* (Cke.) Demaree and Cole.

BROWN LEAF SPOT

Brown leaf spot [3] is one of the most common leaf diseases of the pecan and is distributed throughout the pecan belt. A pecan leaf with the characteristic markings of brown leaf spot is shown in Figure 4. The spots are circular to irregular in outline and vary from one-eighth to one-half inch across. They are usually reddish brown, but the older spots often become grayish and develop concentric zones.

FIGURE 3.—Pecan leaf blotch. During this stage the spots are made up of many small black, pimplelike bodies

This disease rarely appears before the 1st of July, and only fully grown leaves that have developed the dark-green color are susceptible. The disease may increase rapidly after midseason, frequently causing total defoliation.

The Stuart is the most susceptible of the commonly grown varieties. The Moneymaker also may be injured seriously, while the Frotscher and Schley varieties are more resistant.

Until very recently the disease has been considered one of minor importance. Although present in all orchards for many years, the spots have not been sufficiently abundant to cause much damage. Young trees and those of maximum vigor are the most resistant; trees subjected to strong competition on account of close planting, those suffering from a lack of proper cultivation and fertilization, and those affected with rosette are most seriously damaged.

Premature defoliation of the Stuart variety by brown leaf spot is now becoming a common occurrence even in orchards

[3] Caused by *Cercospora fusca* Rand.

under good management. The leaves become badly infected in August; and defoliation, beginning about the 1st of September, may be completed in three or four weeks.

METHODS OF CONTROL

Brown leaf spot and leaf blotch, although caused by different organisms, are both controlled by the same treatments with copper fungicides. Because these diseases were of little economic importance until recently, pathologists did not give them the attention they now deserve, and no definite spray schedule has been formulated. Observations have shown that in numerous cases three and four applications of Bordeaux mixture intended to control pecan scab entirely prevented infections by leaf-blotch and brown leaf-spot fungi. Figure 5 shows the results in controlling leaf blotch by dusting with a mixture of 20 per cent monohydrated copper sulphate and 80 per cent hydrated lime, and Figure 6 shows what may be done in controlling brown leaf spot with one application of Bordeaux mixture in late July.

For the protection of pecan foliage against damage from these two diseases, it is tentatively recommended that two applications of Bordeaux mixture or three applications of copper lime dust be made during June and July, beginning about June 15. If the liquid is used, the second application may be made about the middle of July, but the intervals between the applications of dust should be not more than three weeks.

FIGURE 4.—Brown leaf spot of pecans

NURSERY BLIGHT

Pecan nursery blight is a leaf disease [4] of young nursery trees and occurs rarely in orchards.

[4] Caused by *Phyllosticta caryae* Peck.

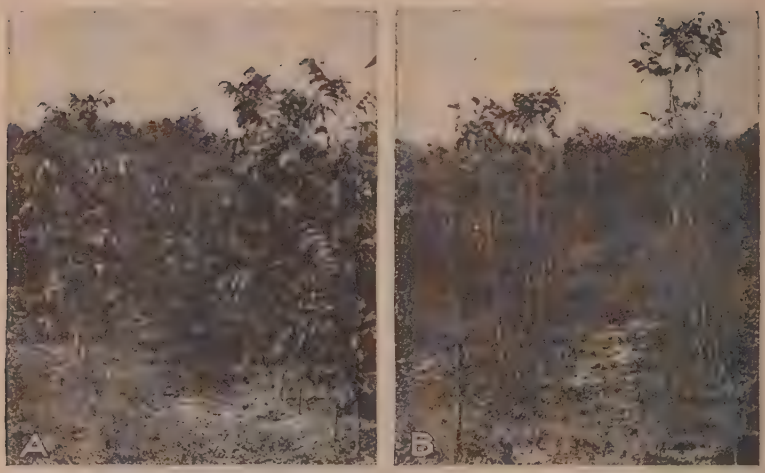


FIGURE 5.—Pecan leaf-blotch control; A, Trees dusted five times with a mixture of 20 per cent monohydrated copper sulphate and 80 per cent hydrated lime; B, untreated plot. (Both plots photographed November 16, 1928)

FIGURE 6.—Pecan leaf-spot control. Trees in the background not sprayed. The one tree in the foreground was sprayed once in late July with a 3–4–50 Bordeaux mixture. (Stuart variety; photographed November 23, 1929)

It is widely distributed throughout the southern pecan belt, and is of considerable economic importance in pecan nurseries because in wet seasons it causes heavy defoliation. Pecan seedlings badly affected with nursery blight make little growth and sometimes are too small for budding at the end of the second year's growth, when most of the budding is done.

The disease first appears in April as small reddish spots on both sides of the leaves; later the color of the spots on the upper surface turns gray. Spots are most abundant along the veins or the margins of the leaves. The dead leaf tissues become brittle and break out, leaving irregular ragged margins and perforations. (Fig. 7.) Single spots are seldom more than one-eighth of an inch in diameter, but two or more spots may unite. While late-season infections may occur at any point on the upper leaf surface, they most commonly occur along the midribs and larger veins, as illustrated in Figure 8.

Nurserymen who spray to control this disease make four or five applications of Bordeaux mixture at intervals of three or four weeks. The first application should be made soon after the first leaves have formed and before infections have begun.

FIGURE 7.—Nursery blight on young pecan leaflet

CROWN GALL

Crown gall,[5] as the name implies, manifests itself as enlargements on the roots or collars of the trees. Figure 9 shows a typical case of crown gall on a nursery tree. On account of its rare occurrence it has been considered a distinctly minor disease of pecan trees in orchards. It is more often seen on young trees as they are dug from the nursery row. Nursery trees should be inspected before planting, and those showing such enlargements should be discarded.

[5] Caused by *Bacterium tumefaciens* Smith and Town.

POWDERY MILDEW

The powdery-mildew fungus [6] forms a white superficial growth on both leaves and nuts of the pecan. It appears during May, June, and July, especially in seasons of considerable rainfall and high humidity. Owing to its habit of coating the leaves and nuts with the white powdery growth, it frequently causes growers some concern. Usually, infected nuts develop normally and show no evidence of injury, but occasionally considerable damage is done to the most susceptible budded trees and planted seedlings in the piedmont region of Georgia. Severe cases that result in a reduced size of nuts and shriveled kernels are comparatively rare. The Pabst is the most susceptible of any of the more commonly grown varieties.

FIGURE 8.—Pecan nursery blight as it often appears on mature leaflets

WESTERN SOOTY SPOT

The western sooty spot [7] is a pecan-leaf disease, confined, so far as known, to Texas and Louisiana. It has been found in Oklahoma and Georgia on hickory leaves and probably is present in Oklahoma and Arkansas on the pecan.

Circular spots one-fourth to one-half of an inch in diameter develop on the under sides of the leaflets during midsummer and are not very different in color from the adjacent leaf tissues, being greenish brown and, therefore, inconspicuous. (Fig. 10.) They can best be seen at this stage when held against a strong light. During October, when the diseased tissues die and change to a lighter color, minute, black, pimplelike structures containing spores appear in the spots. At this time the spots are evident also on the upper side of the leaflet.

[6] *Microsphaera alni* (Wallr.) Wint.
[7] Caused by *Gloeosporium caryae* var. *curvisporum* Dearn.

GNOMONIA LEAF SPOT

The Gnomonia leaf spot[8] is another pecan disease of minor importance, occasionally observed in Florida and the southern part of Georgia. It first appears in June as a small, inconspicuous brown spot with no certain diagnostic features. The spot may enlarge to one-half of an inch or more in diameter and become almost black in color. The shape of the spots varies from circular to greatly elongated. The most distinguishing characteristic of the Gnomonia leaf spot is that affected areas are frequently confined to a narrow space between two lateral veinlets, forming a long narrow dead area. (Fig. 11.) The disease has not become serious enough to justify the use of remedial measures.

FIGURE 9.—Crown gall on pecan nursery trees

DOWNY SPOT

Downy spot[9] is a name given to a leaf disease first found on hickory trees in Ontario, Canada, in 1889, but not observed on the pecan until 1926. White or downy spots appear on the under sides of the leaves during the latter part of May or early in June. (Fig. 12.) These are made up of innumerable spores or conidia of the fungus, which are easily washed off by rains, leaving faint yellowish spots. Later these spots may change to brown and extend through to the upper sides of the leaves. In 1927 this disease in southern Georgia was serious enough to cause some defoliation. The following year it was much less in evidence. How important it may become is not known at present. The Delmas and Moneymakers seem to be more susceptible than the other commercial varieties.

The writer has conducted no experiments for controlling this new disease of pecans, but the fact that five and six applications of the monohydrated copper sulphate and lime dust used to prevent scab had no effect indicates that it may be hard to control.

WOOD ROTS

Wounds made in pruning pecan trees and those arising from other mechanical injuries, such as careless cultivation, winter injury,

[8] Caused by *Gnomonia* sp.
[9] Caused by *Cercosporella caryigena* (E. and E.) Von Hohnel.

and windstorms, are all possible points of entrance for wood-rotting fungi. The hot, humid climate of the Southeastern States favors the rapid development of these fungi; and unless wounds are given protection from infection and so handled as to facilitate healing, it is inevitable that fungi will gain entrance and endanger the life of the entire tree.

Growers wishing to change the varieties in their orchards to more desirable ones cut back the tops of the trees and bud or graft to the selected variety. In many instances this necessitates severing large limbs and making wounds that require two or more years to heal. When removing a limb, the orchardist should make a preliminary cut on the under side about one-quarter through the limb, as a safeguard against splitting the limb or tearing off the bark. When removing a limb entirely, he should make the second cut almost flush with the body of the tree, as such a wound heals more readily. (Fig. 13.) Entrance of wood-rotting fungi into wounds can usually be prevented by painting the cut surface carefully and thoroughly with some antiseptic tree-wound dressing. Ready-prepared wound dressings may be purchased or a good paint prepared at home by combining coal tar with creosote. A sufficient quantity of creosote should be mixed with the coal tar to form a paint of such consistency that it can be spread readily with a brush. Ordinarily the proportion will be about 1 part of creosote and 4 parts of coal tar. The wound should be painted immediately after it is made, and once or twice annually thereafter until completely healed.

FIGURE 10.—Pecan western sooty spot as it appears during midsummer

DISEASES DUE TO ENVIRONMENTAL FACTORS

ROSETTE

In its earliest stages, or on slightly affected trees, rosette is indicated by a slight yellowish mottling of the leaves. In more distinct cases the leaflets are slightly narrowed and crinkled. When trees are severely affected the leaflets are extremely narrowed, with

either reddish-brown areas or perforations between the leaf veins. (Fig. 14.) Checking of the new twig growth causes the shortened internodes and the bunching of the foliage that have suggested the name rosette. In the final stages of the disease the twigs die back from the tips. Usually the dying back is confined to the current year's growth, but sometimes in severe cases of rosette it extends to branches of considerable size. Seriously affected trees rarely bear nuts, and those borne may be small. The writer has never seen a tree that has died as the direct result of rosette, but affected trees frequently become so weakened and misshapen as to be worthless. (Fig. 15.)

The cause of pecan rosette is not definitely known, but it is in some way related to unfavorable soil conditions.

With few exceptions there is not much variation in the susceptibility of varieties to rosette. The Stuart is probably the most susceptible, with Van Deman and Frotscher following closely. Of the varieties exhibiting resistance, the Moneymaker is the only one of outstanding merit in this respect. This variety is strikingly resistant and though not of high quality is probably the best to use to top-work rosetted trees where other methods recommended for curing the disease have failed. If orchards are to be planted in deep sandy soils, impoverished soils, or other soils that may induce rosette, the Moneymaker variety is the best to plant, but planting to any variety in such soils is not likely to be profitable.

FIGURE 11.—Gnomonia leaf spot on pecan. Delimitation of the spots by the leaflet veins is characteristic of the disease

The disease is found in all Southern States from Texas to North Carolina, but there is a marked difference in the number of affected trees in different localities. Although rarely found in native pecan forests along the rivers of Texas and Louisiana, the disease frequently occurs in orchards planted on the upland soils of these States. By far the greatest

number of rosetted trees is found in orchards planted on the typical sand, sand-clay, and clay soils of the Atlantic and Gulf coastal plains. The disease is most prevalent on deep sandy soils, eroded hillsides, impoverished cotton lands, and soils with a stiff, semi-impervious subsoil. In the coastal-plain regions trees growing in any soil deficient in humus may become rosetted. The disease seldom affects an orchard uniformly, but attacks those trees growing on the lighter and sandier soils. Trees growing in low places where humus and fertilizing materials accumulate are usually thrifty and free of rosette. There are, however, some apparent contradictions to these observations.

FIGURE 12.—Downy spot of the pecan. During an early stage of the disease the markings are white, caused by the presence of innumerable white spores. Rains wash away the spores, leaving faint yellowish areas

Sometimes rosette is present in trees growing in what appears to be a very fertile soil, but borings usually will reveal that this soil is underlain with a thick stratum of sand or hard, impervious clay. In the delta of Louisiana, rosette sometimes affects trees growing on fertile garden soils or near barns, pigpens, or feed lots, where its presence may be due to a lack of balance in the supply of plant-food materials or to a deficiency in some of the essential elements, such as calcium.

TREATMENT

On soils readily susceptible to improvement, rosette may be overcome by consistently following some soil-building program. This program should include as its principal feature the application of organic matter in some form to the soil each year. Applications of stable manure have consistently given the quickest and most striking results. Leaf mold, swamp muck, undecomposed forest leaves, and cane pomace, either used as a mulch or plowed into the soil, have given good results. In the larger orchards the growing and plowing under of leguminous cover crops have proven to be the most practical and successful

remedy. Ordinary commercial fertilizer alone apparently is not a direct remedy, but its use with the cover crop is highly advantageous, not only in furnishing plant food to the trees but in inducing a more luxuriant growth of the cover crop to be turned under. The writer has considerable evidence that frequent summer cultivation, especially if deep, favors the occurrence of rosette. Therefore, until there are adequate experimental data to disprove this theory, it may be advisable to reduce the depth and number of cultivations in rosetted orchards to a minimum consistent with good horticultural practice.

Restoration of rosette-affected trees is usually slow, and attempts to cure the disease are frequently discouraging. A badly rosetted tree is slow to respond and requires at least two years of treatment before results are evident. The time required to effect recovery depends upon how intensively the corrective measures are used and also upon the nature of the soil. In some instances where the subsoil is composed of a stratum of sand more than 2 feet thick it may be best to abandon the trees.

FIGURE 13.—Wound left by removal of a large limb. Such wounds heal more readily if the cut is made almost flush with the trunk

SAND BURN

Sand burn is a name applied to a dying of young pecan seedlings during their first year of growth and is caused by excessively high temperatures of the surface soil. The young seedlings are girdled near the ground, or the terminal bud is killed as it attempts to push through the hot surface layer of soil. The portion of the seedling above the girdled area dies gradually, the leaves blacken and usually remain attached. The uninjured part of the seedling below the girdled section may send up one to several shoots, simultaneously or successively, which in turn may be killed as the terminal bud reaches the surface of the hot soil. (Fig. 16.)

Sand burn is frequently the most important factor contributing to poor stands of seedlings in pecan nurseries. It causes greater mortality when the seeds have been planted late, when seeds of poor quality have been used, and when high temperatures occur during May and June following the planting. Therefore, the planting of high-grade nuts during the early part of the winter, the avoidance of deep sandy soils devoid of humus and subject to overheating, and the selection of a nursery site having no westerly exposure are recommended as measures tending to lessen the danger of heavy loss by sand burn.

Work done at the United States Pecan Field Station near Albany, Ga., indicates that the trouble can be practically eliminated if the

seedlings are grown the first season in close beds under partial shade and transplanted to the open field the following year.

FIGURE 14.—Pecan rosette. A pecan leaf affected with rosette, showing narrow, crinkled leaflets with perforations

LITTLE LEAF

In the more pronounced cases of pecan little leaf, the leaflets are both shortened and narrowed, the width being reduced to about one-third of an inch. The leaf itself is often reduced to a length of

only ½ to 2 inches, exclusive of the petiole, or leaf stem. A slightly affected leaflet may be normal in size, the only visible symptom of the disease being the obtuse apex. (Fig. 17.) Some trees observed

FIGURE 15.—A typical specimen of a badly rosetted pecan tree

have been so severely affected that all their leaves were composed of leaflets of the extremely rounded and diminutive type. In other trees the disease may be found only on certain branches, recurring there each year while other limbs of the same trees produce normal

leaves and twigs. Badly affected trees do not bear nuts, and their growth is greatly retarded. The writer has evidence that some trees recover after one or more years, while it is definitely known that the trouble has persisted in others for a number of years.

FIGURE 16.—Sand burn of pecan seedlings: A, How the sprouts are killed as they emerge from the soil surface; B, a seedling girdled just above the ground line; C, the second seedling from the right is normal; the others are either dead or dying

The disease is of minor importance, as it seldom affects trees growing under orchard conditions. When found it is usually in trees growing in city gardens and lawns. It has been seen in a number of towns in States bordering the Atlantic and Gulf coasts

from North Carolina to Mississippi. Experiments indicate that little leaf is not transmissible from diseased to healthy trees and is not becoming noticeably more abundant. The cause of the disease is not known.

WINTER INJURY

Winter injury causes an annual loss of many young pecan trees and is considered a rather serious problem by owners of young

FIGURE 17.—Little leaf disease of pecan

orchards. The symptoms are quite striking. Injured trees put out leaves in the spring as if normal and grow for several weeks on the food stored in the trunk and limbs, then suddenly wither and collapse. An examination made at this time reveals that parts of the trunk had been previously injured, as evidenced by the discolored inner bark and by the sour odor. The original injury may have been confined to a narrow band near the surface of the ground, but by girdling the trunk it sufficed to cause the tree to die above ground. The roots of affected trees as a rule do not die, but send out sprouts from below the dead parts. (Fig. 18.) Soon after the bark tissues

are damaged almost invariably shot-hole borers riddle the bark with many small holes; growers consequently often attribute the dying of the trees to borer infestation.

Winter injury is caused by sudden and excessive changes in temperature during the late fall and winter. Young trees 3 to 5 years old that have made a late growth are the most susceptible. Trees over 9 or 10 years of age are seldom infected.

FIGURE 18.—Winter injury of a young pecan tree. The leaves developed normally during early spring and then died in May. Later in the season sprouts formed from the uninjured roots

To guard against dangers of winter injury, young orchards should not be given deep cultivation or nitrogenous fertilizers during the latter half of the growing season. If the growth of the trees is stimulated during the fall, their susceptibility to winter injury is increased. Loss of young trees by winter injury can be entirely prevented by wrapping the trunk of each tree during the fall with a gunny sack, as shown in Figure 19.

A few growers make a practice of splitting the bark of frozen trees. There is no merit in this supposed remedy; indeed, it may cause much harm by exposing the underlying bark and cambium tissues to fungus infection.

EDEMA

Infrequently spots of striking character form on the trunks of young pecan trees, as illustrated in Figure 20. They are light or cinnamon brown, slightly raised, and often cracked. The interior of the affected areas is composed of dead tissues that are dry and spongy and finally become more or less powdery. They do not extend deep into the bark and apparently cause little or no damage. This trouble belongs to the general type of physiological disease commonly called edema. Diseases of a similar nature have been reported as occurring on other plants. The exact cause of edema is not known.

SPRAYING

Spraying is the principal control measure for some of the diseases under consideration and also for certain insects. A general spray schedule for combating diseases and insects in southern pecan

orchards has been prepared in collaboration with the Bureau of Entomology and appears as Table 1.

TABLE 1.—*Spray schedule for combating pecan diseases and insects*[1]

Application and time	Material	Diseases and insects to be controlled	Remarks
No. 1.—Immediately after pollination has taken place; when the tips of the small nuts have turned brown.	3–4–50 Bordeaux mixture plus 40 per cent nicotine sulphate at the rate of ¾ pint to each 100 gallons of Bordeaux. To control aphids on nonscabbing varieties use 40 per cent nicotine sulphate at the rate of ¾ pint to 100 gallons of water plus 4 pounds caustic-potash fish-oil soap.	Scab; aphids.	Both surfaces of leaves should be covered for protection against scab and to kill all aphids. For aphid control centers of trees should be sprayed as thoroughly as outer parts.
No. 2.—Three weeks after No. 1.	3–4–50 Bordeaux mixture.	Scab.	A good coverage of the nuts is very important for this and all later applications. If webworms and caterpillars are abundant, add 1 pound calcium arsenate to each 50 gallons of Bordeaux mixture.
No. 3.—Three weeks after No. 2.	3–4–50 Bordeaux mixture.	Scab; leaf blotch; brown leaf spot.	Spray as directed in No. 1. If aphids are present in abundance at this time add 40 per cent nicotine sulphate as in spray No. 1.
No. 4.—Three weeks after No. 3.	3–4–50 Bordeaux mixture; calcium arsenate 1 pound to each 50 gallons Bordeaux plus 40 per cent nicotine sulphate at the rate of ¾ pint to each 100 gallons of the spray (add nicotine last).	Scab; leaf blotch; brown leaf spot; leaf case-bearer; aphids.	Spray as directed in No. 1.

[1] This spray schedule was designed by J. B. Demaree, pathologist, Bureau of Plant Industry, and G. F. Moznette, entomologist, Bureau of Entomology, to meet conditions in southern pecan orchards.

PREPARATION OF BORDEAUX MIXTURE

As stated previously, Bordeaux mixture can be used safely, economically, and effectively in pecan orchards for the control of various diseases. Furthermore, there is no better or cheaper form of Bordeaux mixture known than that made at home with bluestone (copper sulphate), lime, and water.

For the sake of simplicity of equipment, economy of labor, and uniformity of the product, growers are advised to use the powdered or "snow" form of bluestone and a high-grade hydrated lime for making Bordeaux mixture. Powdered bluestone or copper sulphate is in particles about the size of granulated sugar and dissolves rapidly in water. It can be dissolved while the spray tank is being filled. Probably the most practical way to dissolve this powder is to place the required amount in a closely woven sack suspended within the tank and allow the inflowing water to wash through it by inserting the end of the intake hose in the open end of the sack. The "snow" form of bluestone costs slightly more than the large crystals, but the added cost is offset by the saving of time and labor in dissolving it. Hydrated lime can be purchased almost anywhere in 50-pound paper sacks. Although hydrated lime as ordinarily sold in the Southeastern States, especially that manufactured in Alabama and Tennessee, is usually satisfactory for making Bordeaux mixture, growers nevertheless should demand that it contain at least 68 to 70 per cent calcium oxide. The use of hydrated lime

has several advantages. It is properly slaked when purchased, and if stored in a dry place will not deteriorate rapidly; it is relatively free from grit, and a suspension, or "milk," may be prepared in less time than is required with quicklime. The only equipment necessary is a tub or keg in which the lime can be mixed with enough water to make a milk of lime that pours readily. Investigations have shown, however, that dry hydrated lime disperses slowly in water, and therefore makes a better grade of Bordeaux mixture if allowed to soak for an hour or more before the spray is made.

FIGURE 19.—Method of wrapping young pecan trees with gunny sack or burlap to prevent winter injury

A 3–4–50 Bordeaux mixture for use in a 300-gallon power-spray outfit may be prepared in the following manner:

Weigh out 18 pounds of powdered bluestone (copper sulphate) and 24 pounds of hydrated lime.

Start filling the tank with water. The bluestone should be dissolved within the tank while it is being filled as described above. When the tank is about three-fourths full, the engine should be started, to operate the agitator; and when all the bluestone is dissolved, the milk of lime should be added slowly. If a spreader or an insecticide is to be used it should be put in after the milk of lime.

Complete filling the tank with water and spray is ready to be applied.

THE SPRAY OUTFIT

In the past there has been a tendency among pecan growers to provide themselves with small-sized spray outfits that were usually equipped with small motors capable of developing only 3 to 5 horsepower. Without exception, machines of that type have proved decidedly unsatisfactory in bearing pecan orchards and have been the source of many discouraging attempts to combat pecan pests.

Very heavy portable outfits such as are used in the fight against forest-tree insects in the New England States or machines designed for park and roadway tree spraying are at present also unsuitable for pecan-orchard spraying, chiefly because their weight is a drawback when they are used in wet or cultivated fields.

Stationary spray outfits have not as yet been given a fair trial in pecan orchards, and they can not at present be recommended. Unless a tower can be employed it is doubtful whether stationary outfits, with the spray guns now available, will prove satisfactory in pecan orchards where the trees are over 40 feet in height.

What may be termed the medium-sized high-pressure portable spray outfits have given the best service. Such machines are equipped with motors capable of developing from 15 to 20 horse-

power and have pump capacity ranging from 25 to 35 gallons per minute. A tank holding 300 gallons of spray mixture is most generally used. When selecting a machine for pecan-tree spraying the following points should be considered: The pump should possess a capacity greater than is required to operate at least two spray guns; one gun should be of the long-distance mist type capable of discharging from 15 to 20 gallons of liquid per minute; the other gun may be of a smaller type which will discharge 5 to 8 gallons per minute; and the motor must possess sufficient power to operate the pump with both guns open and yet maintain a pressure of 300 to 400 pounds as indicated on the pressure gauge when connected to the pump.

Each spray outfit should be provided with two leads of hose. The one that conveys the liquid to the long-range gun operated from the tower should be three-fourths inch in diameter and need not be over 15 or 20 feet in length. The hose that carries the spray to the small spray gun used on the ground can be one-half inch in diameter, but should be 50 to 75 feet long. The length will depend upon the distance between the trees, as the work with the small gun should precede by one tree that of the long-distance gun so that the drip from the tops of the trees will not interfere with the efficiency of the close spraying. All hose should be equipped with clamp couplings that will not blow off when operating under a pressure of 300 to 400 pounds.

A tower is considered a necessary adjunct to any spray outfit used in pecan orchards over 15 years old. (Fig. 21.) The ordinary short spray gun can not be expected to furnish good distribution beyond 20 to 25 feet from the ground. Some pecan trees are now 60 feet and over in height, and even when the long-distance spray gun is used, their tops can not be well sprayed without a tower.

FIGURE 20.—Edema on the trunk of a young pecan tree

APPLYING THE SPRAY

The first scab application is made at a time when a large majority of the leaves are susceptible to scab infection. It is important, therefore, to give the leaves adequate protection. Since the lower surface of pecan leaves is most susceptible to infection by the scab

organism, one gun operator should work under the trees directing the spray upward and distributing it to the undersurface of the leaves of the lower limbs and to those leaves, twigs, and nuts growing inside the periphery of the tree not easily covered from the tower.

The early-formed leaves are practically immune to scab infection

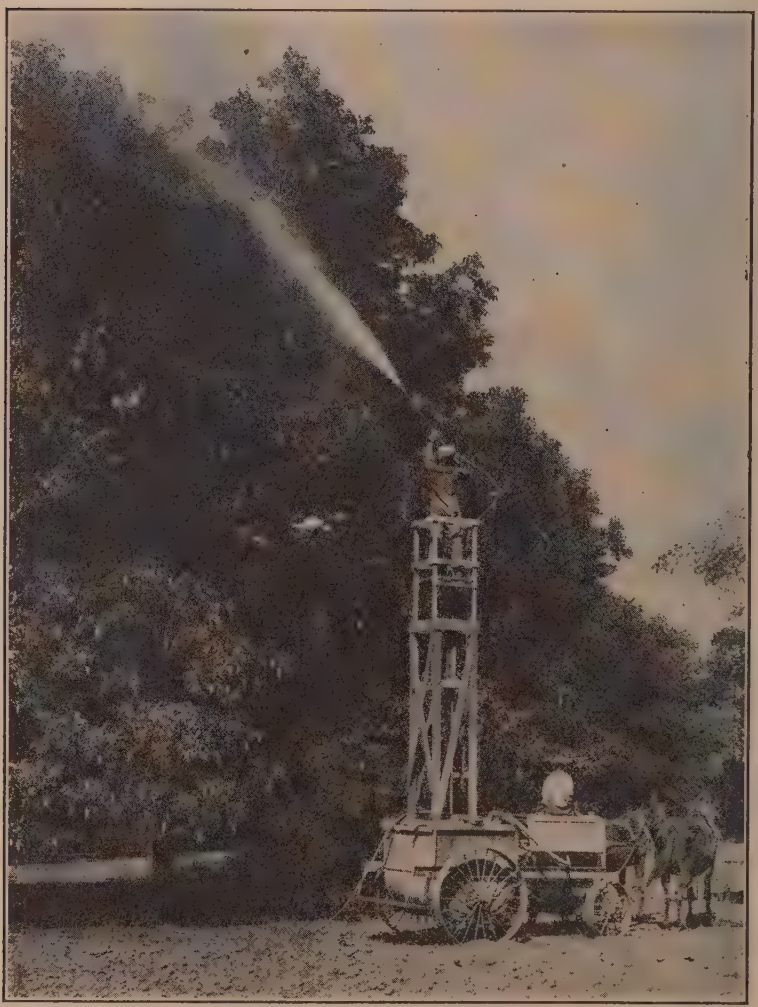


FIGURE 21.—A tower is a necessity when tall pecan trees are sprayed

by the time the second application is made. Therefore, leaf coverage is not so important after the first application has been made except that all new leaves formed during the intervals between applications should be protected with the fungicide. As far as combating scab is concerned, the purpose of the last three applications is primarily to protect the nuts. A very large percentage of the early

scab spots appear on the upper portion of the nuts; therefore, spray directed from the top of a tower will furnish better protection than that directed from the ground. Only those nuts that are given a complete coverage of spray are well protected. The man with the long hose on the ground should concern himself chiefly with the leaves and nuts on the lower branches and the inner lower part of the tree. His work is considered important as he can more readily cover the lower side of nuts and leaves of the lower branches. His work is especially valuable in combating foliage diseases, leaf case-bearers, and aphids. The operator in the tower should direct the spray at different horizontal angles as the trees are being passed so that all sides of the nuts may be covered. Spray must be directed from two sides of each tree. The spray machine should be conveyed along one side of the tree row and back along the opposite side. When spraying large pecan trees the machine should pause at least twice in passing a tree so as to give the nozzle operator time to cover all parts within range. The first stop should be made on approaching the tree, and the second may be made just after the center of the tree has been passed. The exact position of the stop in relation to the tree will depend somewhat upon the direction and velocity of the wind, and also on the position of the larger branches on the side being sprayed. The operator should always take advantage of open spaces between the large limbs to spray distant parts of the tree top.

If a large acreage of trees is to be sprayed, much time and expense will be saved if the water and spray materials are conveyed to the spray outfit in a supply tank having a capacity equal to that of the spray tank. This will permit the spray machine to operate continuously except for the short time required to transfer the water from the supply tank to the spray tank. The driver of the spray outfit should be able not only to drive but to keep the motor and pump in working order; he will be all the more valuable if he can exchange places with the man operating the spray gun.

Pecan growers as a rule have attempted to spray too many trees with a limited equipment. As a result the applications have not been well timed; the spray operators have been compelled to sacrifice thoroughness for speed; and the machines are worked to full capacity for days at a time with little attention given to repairs and adjustments. The final outcome has generally been poor control and discouragement.

On account of variable factors, such as age or size of trees, condition and capacity of machines, refilling facilities, and type of labor used, it is not an easy task for the grower to determine the number of trees or the acreage one outfit can spray successfully. However, each grower should certainly possess enough machines to spray his scab-susceptible trees within a week or 10 days at the most.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	W. G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	E. L. MARSHALL.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	LEE A. STRONG, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	J. T. JARDINE, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This circular is a contribution from

Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Soil Investigations	A. G. MCCALL, *Chief.*
Division of Soil Survey	C. F. MARBUT, *Principal Soil Scientist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 10 cents